PERSISTENT WEATHER ABNORMALITY

By CHARLES D. REED

[Weather Bureau, Des Moines, Iowa, December 1931]

Certain marked weather abnormalities are known to be persistent. Where great abnormality continues for approximately 30 days and roughly coincides with arbitrary calendar divisions, it is easy to predict that the average temperature of some succeeding months will be above or below normal. No doubt, if sufficient labor were bestowed upon the problem, breaking the time division into other lengths than our present months, considerable might be learned about weather sequence that is now hidden.

In a good many States abnormal weather in January is a fair indication of the weather of February, June of July, July of August, December of January, the autumn of the following winter, etc. In Iowa, and perhaps in some other States,[1] June is a key to the rest of the summer.

The data here used are the State averages and departures from normal published in the monthly State section reports. Careful analysis of these data shows that *the greater the abnormality the more certain the sequence* which adds much to the practical usefulness of the study.

Illinois data for June and July temperature and precipitation are graphically presented in figure 1. Among other things these data show:

In 7 out of 10 cases when June averaged 3° or more above normal, July temperature averaged above normal. There was only one case with June temperature 4° or more above normal, and it was followed by July temperature above normal.

In 8 out of 11 cases when June temperature averaged 3° or more below normal, July temperature also averaged below normal. There are only 2 cases when June temperature averaged as much as 5° or more below normal, and in each case July also averaged below normal.

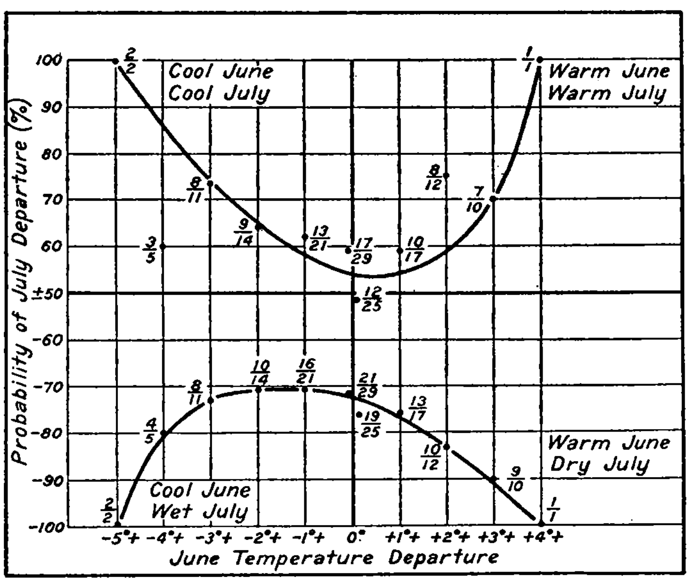

FIGURE 1.—The upper curve shows the frequency and direction of July temperature departures as related to temperature departures of the preceding June in Illinois. The entry, 7/10, means 7 cases out of 10, or 70 percent, probable frequency, represented by a dot. The lower curve shows the frequency and direction of precipitation departures in July as related to temperature departures of the preceding June. When the departures of June and July have the same sign, they are plotted as plus probabilities; when they have opposite signs they are plotted as minus probabilities. The entry at the bottom of the graph, —3°+, means 3° or more below normal.

In 13 out of 17 cases when June temperature averaged 1° or more above normal, July precipitation averaged below normal. In 10 out of 12 cases when June temperature averaged 2° or more above normal, July precipitation averaged below normal; and when June temperature averaged 3° or more above normal, July precipitation averaged below normal in 9 out of 10 cases.

In 8 out of 11 cases when June temperature averaged 3° or more below normal, July precipitation averaged above normal; in 4 out of 5 cases when June temperature averaged 4° or more below normal, July precipitation averaged above normal; and in 2 cases when June temperature averaged 5° or more below normal, July precipitation averaged above normal.

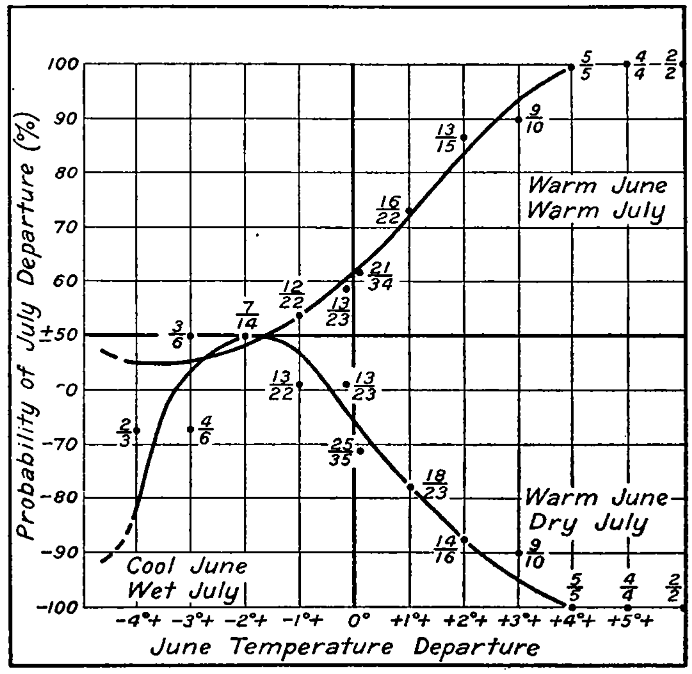

FIGURE 2.—The upper curve shows the frequency and direction of July temperature departures as related to the temperature departures of the preceding June in Iowa. The entry, 13/15, means 13 out of 15 cases, or 87 percent, probable frequency, represented by a dot. The lower curve shows the frequency and direction of precipitation departure in July as related to the temperature departures of the preceding June. When the departures of June and July have the same sign, they are plotted as plus probabilities; when they have opposite signs they are plotted as minus probabilities. The entry at the bottom of the graph, +3° +, means 3° or more above normal.

In all of the above cases the greater abnormality was followed by the more certain sequence. The regular appearance of the curves and the very moderate scattering of the dots gives one much confidence in the results. Also, inspection of the June temperature-July temperature curve shows that the lowest percentage of sequence does not come at the normal but 1° or so above normal; and the June temperature-July precipitation curve shows that the lowest probable sequence comes at 1° to 2° below normal rather than at the normal.

In all of the above, temperature was taken as the indicator. If June precipitation be tried as an indicator, the results are not nearly so regular. However, it is noted that there are 3 cases when June precipitation was 3 inches or more above normal, and in each case July precipitation was above normal. June precipitation departures seem to have very little relation to temperature departures of the following July in Illinois.

Within the limits of this paper, it is possible to present but a small portion of the data that have been studied. Figures 2 and 3 are the June-July curves for Iowa. Here

[1] MONTHLY WEATHER REVIEW, June 1925, pp. 249-251.

the June precipitation departure is more of an indicator of July weather than it is in Illinois and it has therefore been reduced to a curve. Only a few features can be pointed out.

In 16 out of 22 cases when June temperature was 1° or more above normal, the following July temperature was above normal; in 13 out of 15 cases when June temperature was 2° or more above normal, the following July temperature was above normal; and in 5 cases where the June temperature was 3° or more above normal, July temperature was above normal in every case.

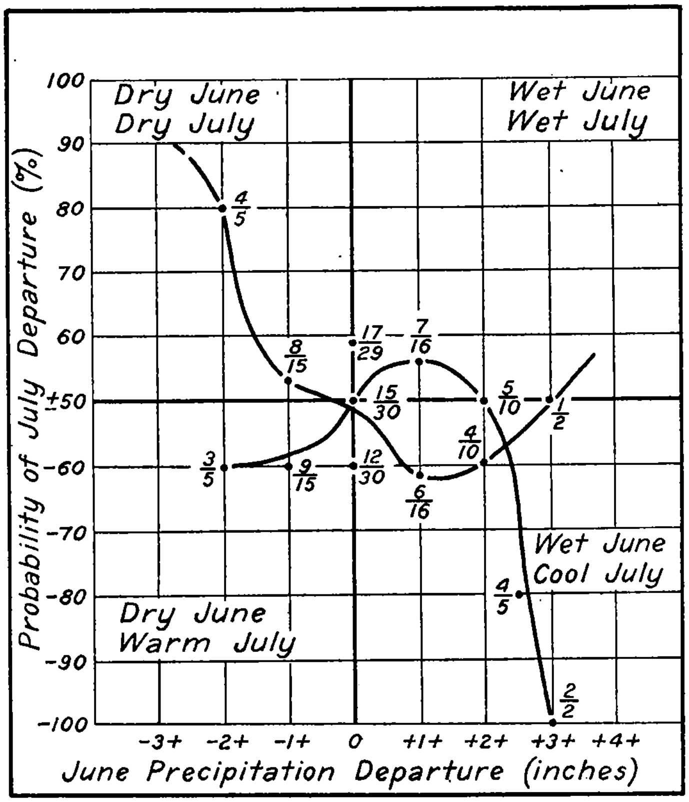

FIGURE 3.—The upper curve shows the frequency and direction of the July precipitation departures as related to the precipitation departures of the preceding June in Iowa. The entry, 4/5, means 4 cases out of 5, or 80 percent, represented by a dot. The lower curve shows the frequency and direction of the temperature departures in July as related to the precipitation departures of the preceding June. When the June and July departures have the same sign they are plotted as plus probabilities; when they have opposite signs they are plotted as minus probabilities. The entry at the bottom of the graph, −1+, means precipitation 1 inch or more below normal.

In 5 cases when June temperature was 4° or more above normal, July was drier than normal every time; in 9 out of 10 cases when June temperature was 3° or more above normal, July was drier than normal; and in 14 out of 16 cases when June was 2° or more warmer than normal, July was drier than normal. When June is abnormally cool, the probability of a wet July is only about 67 percent.

In 4 out of 5 cases when June precipitation was 2.5 inches or more above normal, the average temperature of the following July was below normal, and in 4 out of 5 cases when June rainfall was 2 inches or more below normal, the following July was dry (fig. 3).

Along similar lines, outstanding June-July relationships have been noted in North Dakota, Minnesota, Wisconsin, Indiana, Michigan, New England, Kansas, Missouri, South Dakota, Tennessee, Florida, Oregon, and California. One broad statement can be made, namely, that when June temperature averages 3° to 4° above normal, July precipitation will average below normal nearly 100 percent of the time over much of the Mississippi Valley—a matter of importance in respect to corn and cotton.

In Iowa, June temperature above normal is a good indication that the average temperature of the next 3 months will be above normal.[2] This applies 70 to 78 percent of the time from Calgary, North Dakota, and Minnesota to Missouri and east to Ohio, and in Nebraska. In the five cases in Iowa when July was 4° or more above normal in temperature, the following August was above normal in temperature in each case and when July was 4° or more below normal in temperature, August was below normal in each of 3 cases. Also when July has been as little as 1° or more above normal in temperature, August has been drier than normal in 18 out of 22 cases. When July rainfall was 2 inches above normal, August rainfall was above normal in 6 out of 8 cases, and when 2 inches below normal, August was below normal in 5 out of 6 cases. There is a well defined tendency for abnormal July weather to perpetuate itself in August in Iowa, northern Illinois, and possibly elsewhere.

Another sequence worthy of study is the January-February relationship which is of much importance in some States. Here again the greater the abnormality the more certain the sequence.

Figure 4 shows the curves for Iowa using temperature as an indicator. A cold January is more likely to be followed by a cold February than is a warm January by a warm February. In 14 out of 19 cases when January was 4° or more below normal in temperature, it was followed by a February below normal in temperature. This sequence is higher as the Januarys are colder, reaching 5 cases out of 5 at 10° below normal. At 9° above normal, January is followed by a warm February 3 out of 4 times, and in each of the 2 cases of 10° above normal. A cold January has little significance as to precipitation in February, but a January, 8° or more warmer than normal, is followed by a dry February 5 times out of 6, and in all of the 4 cases of 9° above normal. January and February temperature abnormalities have a tendency to persist through March in Iowa.

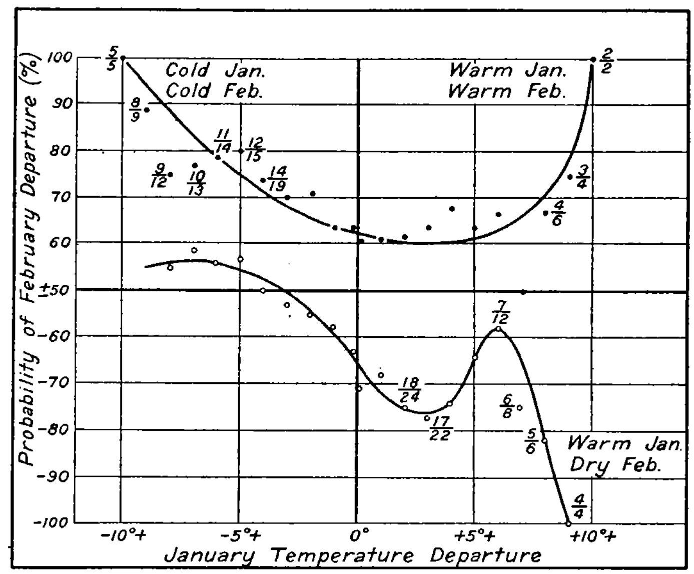

FIGURE 4.—The upper curve shows the frequency and direction of the February temperature departures as related to the temperature departures of the preceding January in Iowa. The entry, 12/15, means 12 cases out of 15, or 80 per cent, probable frequency, represented by a dot. The lower curve shows the frequency and direction of precipitation departures in February as related to the temperature departures of the preceding January. When the departures of January and February have the same sign they are plotted as plus probabilities; when they have opposite signs they are plotted as minus probabilities. The entry at the bottom of the graph, −5°+, means 5° or more below normal.

Precipitation in January, 0.75 inch or more above normal, in Iowa, has been followed by a February colder

[2] MONTHLY WEATHER REVIEW, June 1925, pp. 249–251.

than normal in 4 out of 5 cases, probably due to a persistent snow cover carried over from January into February which would increase radiation.

Similar results are obtained from a study of Wisconsin data (fig. 5). Here a Janaury 4° or more above normal has been followed by a warm February 9 out of 11 times, and a January 6° or more below normal by a cold February 6 out of 7 times. Both excessively cold and excessively warm Januarys have a tendency to be followed by dry Februarys, due to the fact that the normal precipitation of February is made up of a relatively small number of heavy amounts and a large number of small amounts; that is, 65 percent of the Februarys have had below-normal precipitation.

Cold Januarys show marked tendencies to be followed by cold Februarys from the upper Mississippi east over the Great Lakes, Indiana, Ohio, and Pennsylvania; also

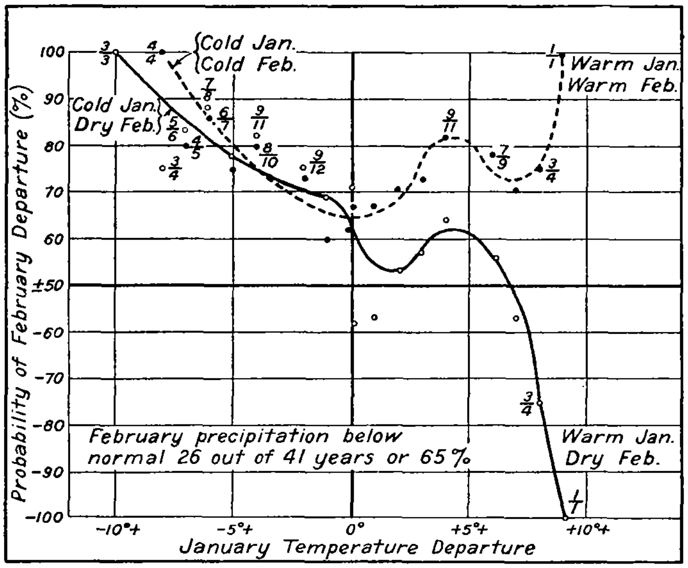

FIGURE 5.—The broken curve, drawn to fit the dots, shows the frequency and direction of the February temperature departures as related to the temperature departures of the preceding January in Wisconsin. The entry, 9/11, means 9 cases out of 11, or 82 percent, probable frequency, represented by a dot. The curve drawn to fit the small circles shows the frequency and direction of the precipitation departures in February as related to the temperature departures of the preceding January. When the departures of January and February have the same sign they are plotted as plus probabilities; when they have opposite signs they are plotted as minus probabilities. The entry at the bottom of the graph, −5° +, means 5° or more below normal.

in the Pacific States, Bermuda, and Manila. The proximity of large bodies of water is probably significant.

Warm Januarys show a fairly well-defined tendency to be followed by warm Februarys in Wisconsin, Minnesota, Indiana, North Carolina, Bermuda, California, Kansas, Texas, Sitka, Berlin, and Greenwich.

The May curves (figs. 6 and 7) for Iowa are here shown without comment.

Whatever the cause or causes of extreme abnormalities may be, they probably set in gradually and increase in intensity till both the records and personal impressions register the unusualness after which it takes a period of similar length with decreasing intensity to return to normal. Being aware of the first disturbing half of the abnormality, the reasonable thing is to expect the other restoring half in a similar period. When a temperature abnormality has accumulated a large departure extending over a 30-day period it is easy to predict another 30-day period of restoration, the average of which will have the same sign of departure as the first month. This seems to happen most frequently in midwinter and midsummer. If shorter period data were in convenient form, no doubt many other useful things might be discovered. For example, it is known that when the first two weeks of June are considerably above normal in temperature at Des Moines, the next two weeks are likely to be above normal. In summer, precipitation abnormalities are usually in the opposite direction from temperature abnormalities. In

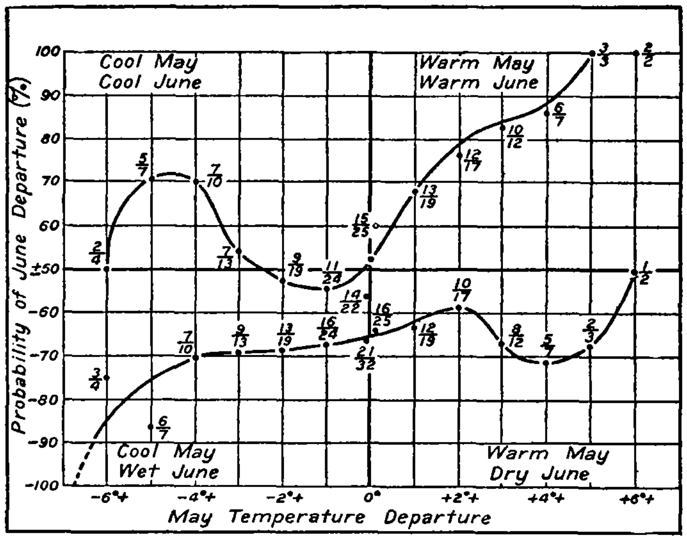

FIGURE 6.—Explanation similar to that of figure 1.

Iowa, the correlation coefficient between July temperature and precipitation in the same month is −0.50.

When conditions are abnormal the meteorologist is most often asked what these conditions portend. It is useful to the forecaster to know that the more extreme the con-

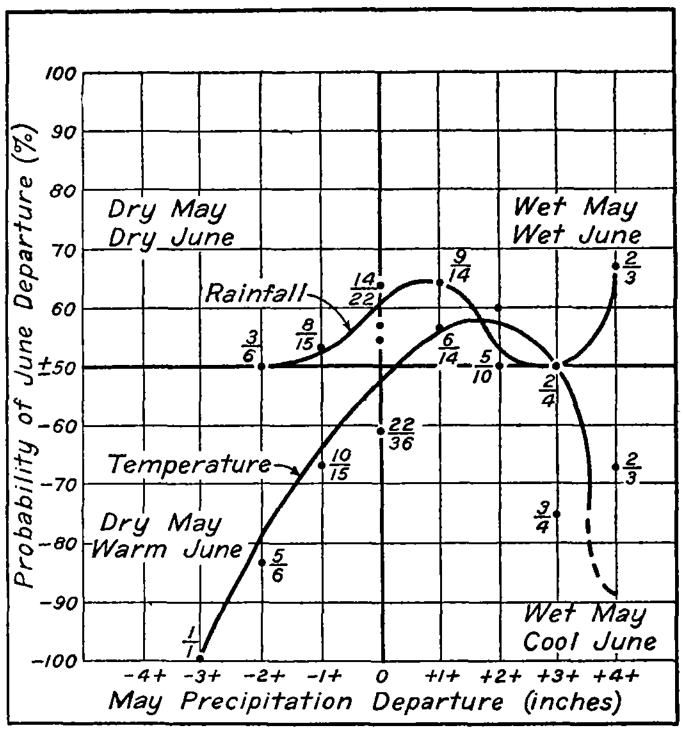

FIGURE 7.—Explanation similar to that of figure 3.

ditions, the more certain are the sequences. Practical applications of these things are left largely to the imagination of the reader. In Iowa, up to July 14, 1931, the season had been almost ideal for corn, but this study made possible the statement that "42 years of carefully recorded experience of the Iowa Weather and Crop Bureau show that only once, 1921, has a large yield followed such a set of circumstances, so deterioration may be expected to set in soon." Following that date, the Bureau of Agricultural Economics of the United States Department of Agriculture showed a reduction of more than 100,000,000 bushels in the estimate of the Iowa corn crop. Such a thing is of vast agricultural and commercial importance. Thus at the close of an abnormally cold January, it would be the best sort of business sense to keep train loads of fuel moving into Iowa. Again a mild January indicates a large number of eggs going to market from Iowa in February and a cold January the reverse.

ON THE OCCASIONS, OR INCIDENTAL CAUSES, OF EXTRATROPICAL CYCLONES

By W. J. HUMPHREYS

Because the earth is continuously warmest within the Tropics and coldest in the polar regions there must be a corresponding amount of ceaseless interzonal circulation of the atmosphere. And because the earth is rotating, this circulation must largely occur in "fits and starts" and cross the middle latitudes in the great swirls and eddies that we call cyclones and anticyclones—must, as has been proved [1] mathematically, and as is evident from the fact that that is the way it does occur.

Cyclones are inevitable. They must occur somewhere, and frequently, for the reasons stated, but exactly when and where they shall start are occasioned or determined by entirely secondary causes. It is these initiating or incidental causes alone that are here considered.

Fundamentally an extratropical cyclone is an extensive eddy or swirl between two winds of different origin, direction, and temperature. Such winds are always blowing. They are the mutually compensating branches of the continuous, interzonal circulation between the warmer and colder portions of the earth. But how are they brought each so decidedly under the influence of the other that an eddy is established between them?

This is effected:

1. By the interplay between oppositely directed warm and cold currents of air adjacent to each other.
2. By a more or less circular, cyclonic rotation, however established, of the air over an extratropical area of suitable size, a process that draws to the western side colder air from higher latitudes and to the eastern side warmer air from lower latitudes.

Considering the first of these methods in greater detail: Owing to the continuous circulation of the atmosphere between the tropical and polar regions warm and cold currents frequently flow side by side in opposite directions, and because of the rotation of the earth the interface between them necessarily is to the left of one going with either current, in the Northern Hemisphere; to his right in the Southern Hemisphere. In this case the two currents of air, though of unequal densities, level for level, may be in equilibrium with each other, the colder wedged at a small angle under the warmer, and flow on without mutual interference—but not for long; the balance is too delicate for that. And wherever the break-down occurs it simultaneously affects both currents. The colder air invades the territory of the warmer while the warmer, on the eastern side of the break, swings into the region of the colder, and, of course, up the interface as up the side of a gently rising mountain. This juxtaposition of distinct air currents occasions most of the extratropical cyclones, and is effective wherever such storms occur. This action is well illustrated by charts A and B.

The second of the two general methods of starting the extratropical cyclone, listed above, may be variously subdivided. One such division is:

a. The invasion of extratropical regions by a cyclone of tropical origin. In this case a continuous storm path may be traced, but not a track of a continuous storm, in the sense of one having all the time the same characteristics. Once it was a mighty whirl in a mass of air of common origin and of substantially the same temperature and humidity on every side, but later, at higher latitudes, and where the conditions already were favorable, it gradually *occasioned* (did not develop or transform into) an extratropical cyclone, or swirl between polar and tropical winds. An excellent example of this sequence of events followed the famous Galveston hurricane of September 9, 1900, as shown on plate C.

b. Persistent relatively high temperature over an area of considerable extent. This causes a greater or less convection over the area in question with a cyclonic circulation round about. In high latitudes, where the influence of the rotation of the earth is strong, this circulation in turn often develops a secondary cyclone in the eastern side of the warmer area. This secondary then moves off as a traveling, independent cyclone and later often assumes large proportions. An example of this genasis of a cyclone is shown on charts D and E.

It must be noted, however, that the particular region shown on these charts, namely, the Gulf of Alaska, is, during the winter, one into which many cyclones come from the west, as well as one from which many emerge to the east. Is it then just a portion of a channel along which the storms pass, as many in as out and substantially unchanged, or is it ever a cyclonic reservoir, as it were, with an outflow more or less independent of the obvious inflow? It is certain that more cyclones leave this region than would if none entered it, and we infer that, owing to its relatively high temperature, the storms leaving it are greater in number than those entering, and commonly different in size and intensity as well—inferences that appear to be abundantly supported by observation. In short, we infer and believe that some of the storms that leave this region had also their origin there, or were occasioned by it.

c. Relatively high temperatures, due to insolation, over land. The cyclones thus induced, "heat" LOWS, they have been called, commonly are feeble and of little importance. A cyclone that appears to have been contributed to in this way, starting as a California valley LOW, is shown on charts F to H, inclusive.

d. The heating of the air over a considerable area by foehn or chinook winds. Charts I to L, inclusive, show a good example of a cyclone initiated in this interesting way.

There is nothing really new in this paper, nevertheless the emphasis on the several examples afforded by the charts may be helpful to at least some students of this daily puzzle, the extratropical cyclone.

I wish here to acknowledge my deep indebtedness to Messrs. G. E. Dunn, assistant to the forecasters, and A. J. Haidle and Welby R. Stevens of the Forecast Division of the United States Weather Bureau, for kindly selecting for me the weather maps used in this article.

[1] Jeffreys, Quart. J. Roy. Meteorol. Soc., 52; 85, 1926.